BONuS Detector Development (Status)

Carlos Ayerbe Gayoso
College of William and Mary
On behalf of the BONuS collaboration
CLAS Collaboration meeting, 17 Jun, 2016

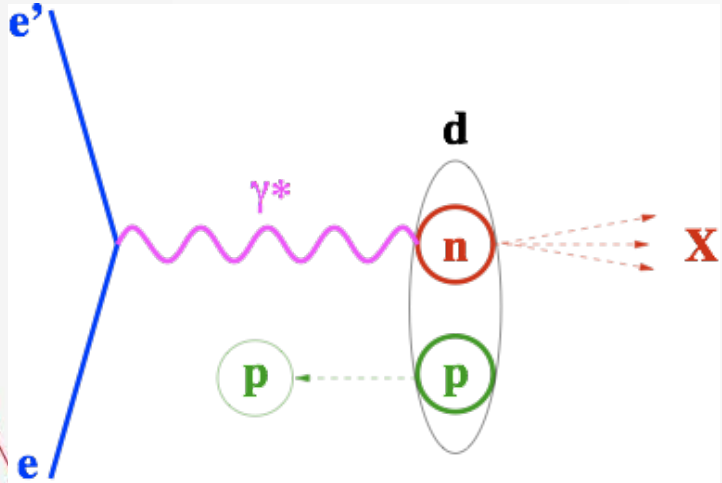
Jefferson Lab
Thomas Jefferson National Accelerator Facility

The College Of
WILLIAM & MARY

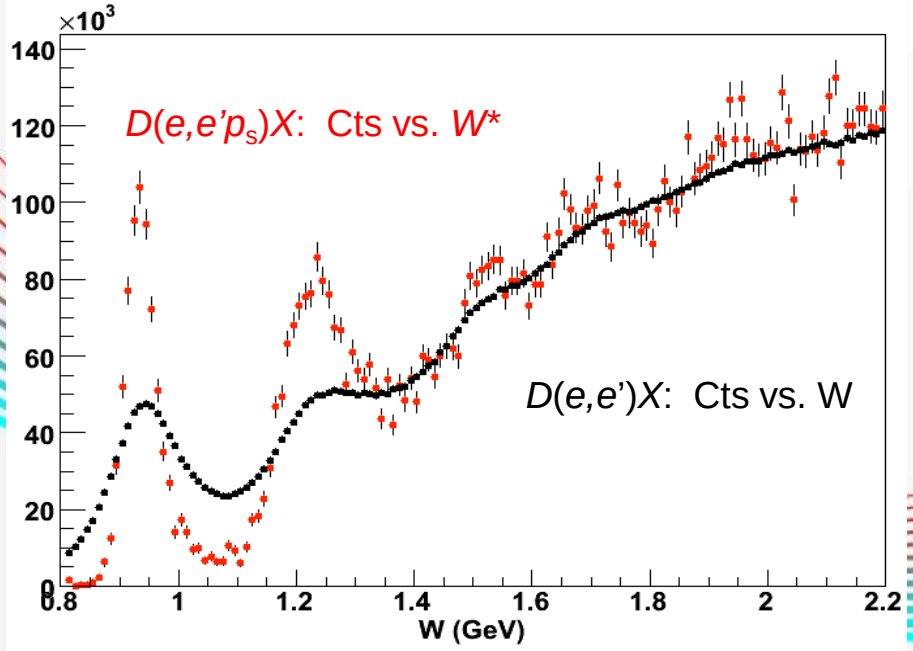
The Experiment

- BONuS12 (**B**arely **O**ff-shell **Nu**cleon **S**tructure) experiment (E12-06-113 PAC36)
- Measurement of neutron SF: Q^2 1 to 14 GeV^2/c^2 and $x \approx 0.1$ to 0.8.
- "Spectator tagging" technique.
  - Detection of low momentum recoil proton (down to 70 MeV/c) in coincidence with scattered electrons.
- Recoil detector based in the RTPC design.

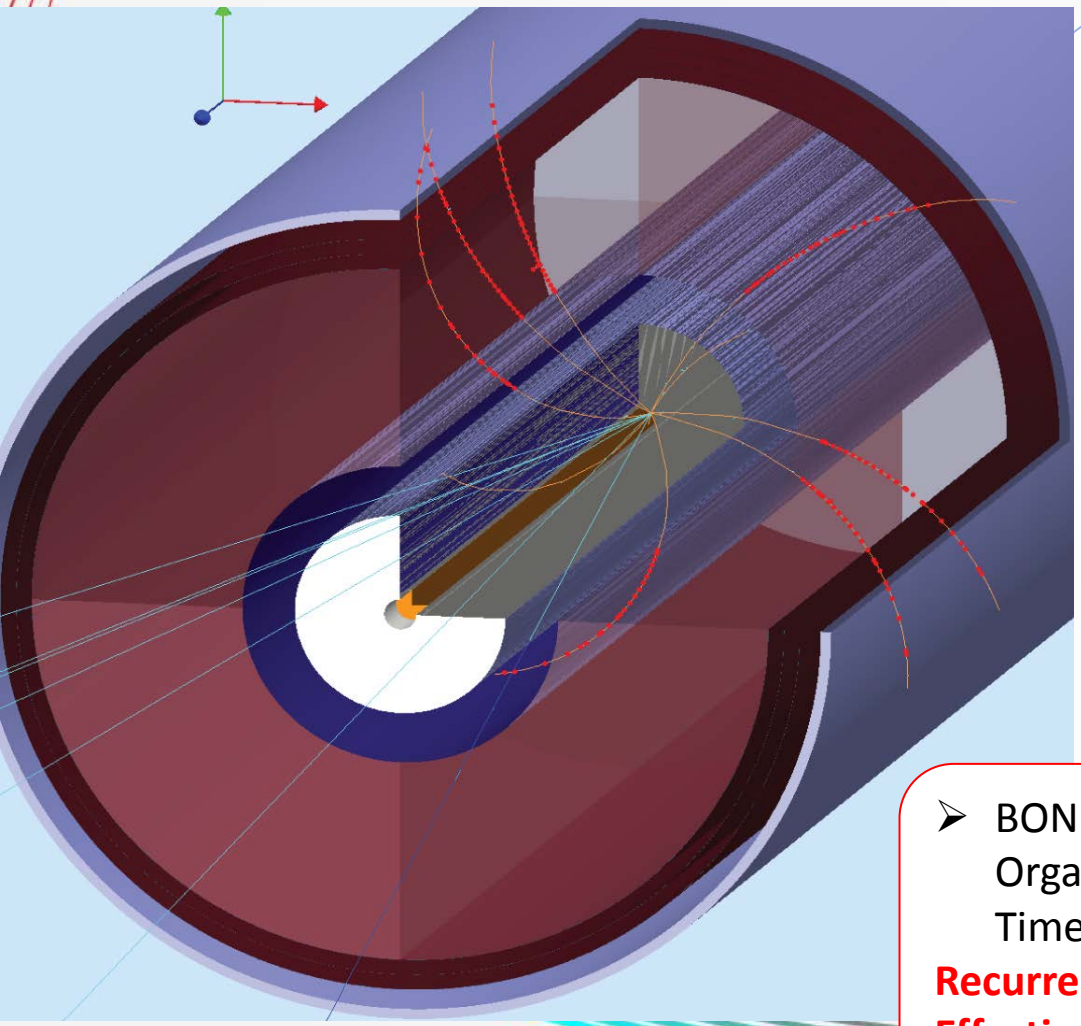
Spectator Tagging Technique



- Low momentum and backward angles minimizes:
  - Final State Interactions
  - Off-Shell Effects
  - Target Fragmentation



BONuS 12 RTPC I

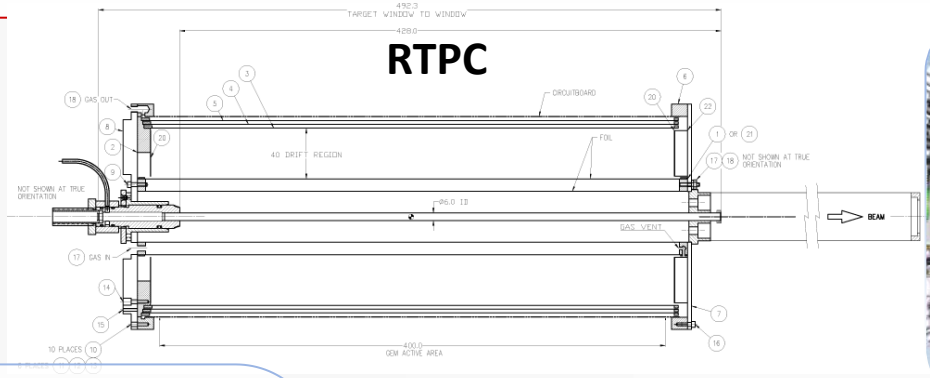


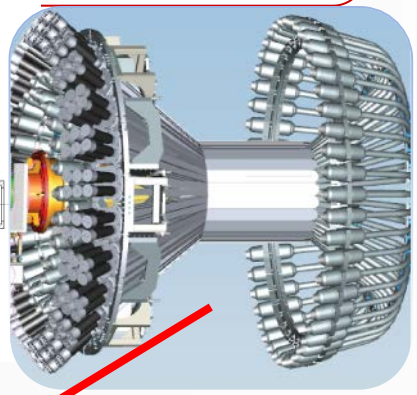
- Target D2, 293K, 7atm, 3mm radius and 40 cm long.
- Target wall 28 μm kapton.
- Drift region: 3<R<7cm
- Drift gas: 293K, 1atm, He/DME (90/10)
- Phi coverage: 360°
- 3 GEM layers separated 3 mm.
- Readout through 100x200 pads. Each pad 4 mm long (Z-direction) and 2.5 mm (Phi-direction).
- Pad signal read by “DREAM” chips from Saclay.

➢ BONuS Design Meeting
Organizer: Sebastian Kuhn
Time: 1:00:00 PM - 2:00:00 PM GMT -05:00

Recurrence : Every Tuesday No end date
Effective Jun 14, 2016

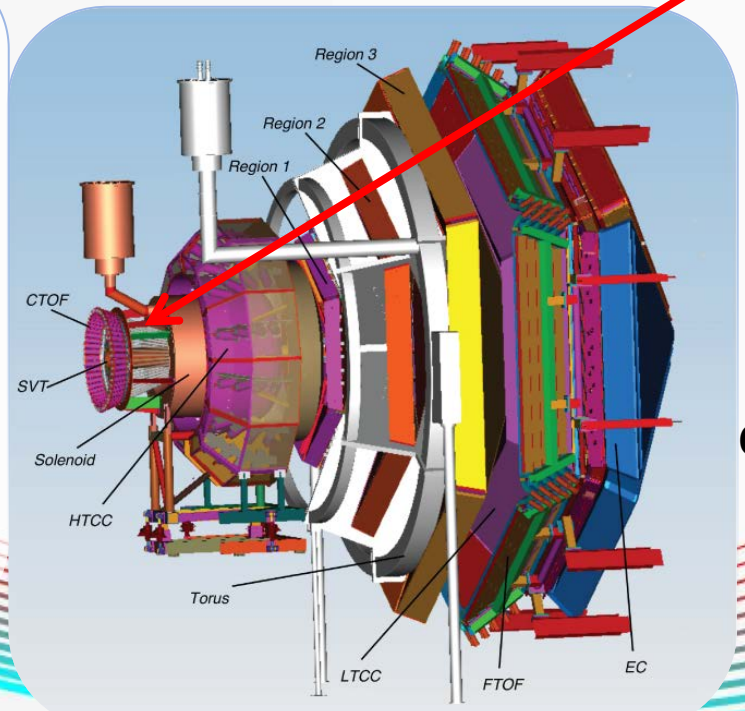
BONuS RTPC II





Central Detector

- Data taking 35 days on D_2 and 5 days with H_2
- $\mathcal{L} = 2 \times 10^{34}\ cm^{-2}\ s^{-1}$
- DIS region
  - $Q^2 > 1\ GeV^2/c^2$
  - $W^* > 2\ GeV$
  - $P_s > 70\ MeV/c$
  - $10° < \Theta_{pq} < 170°$
- Trigger rate ≈ 2kHz
- Read out at 5 MHz



CLAS

NOT TO SCALE

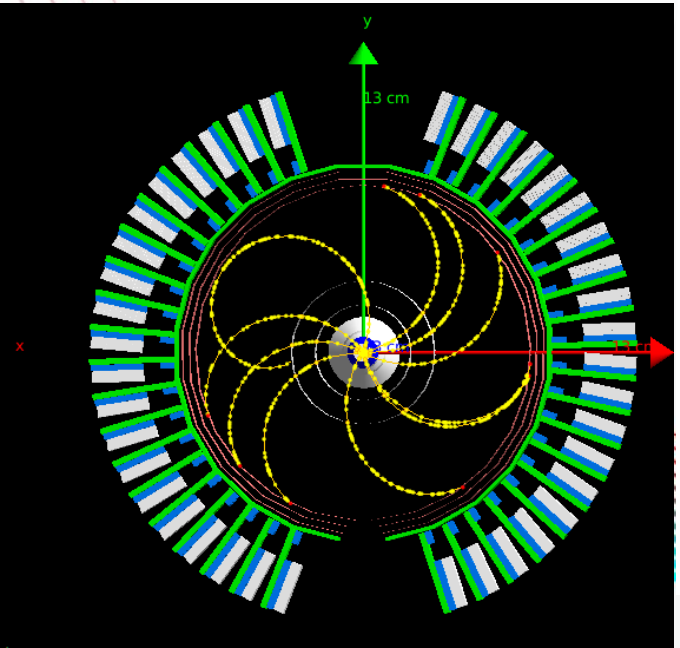
BONuS consortium

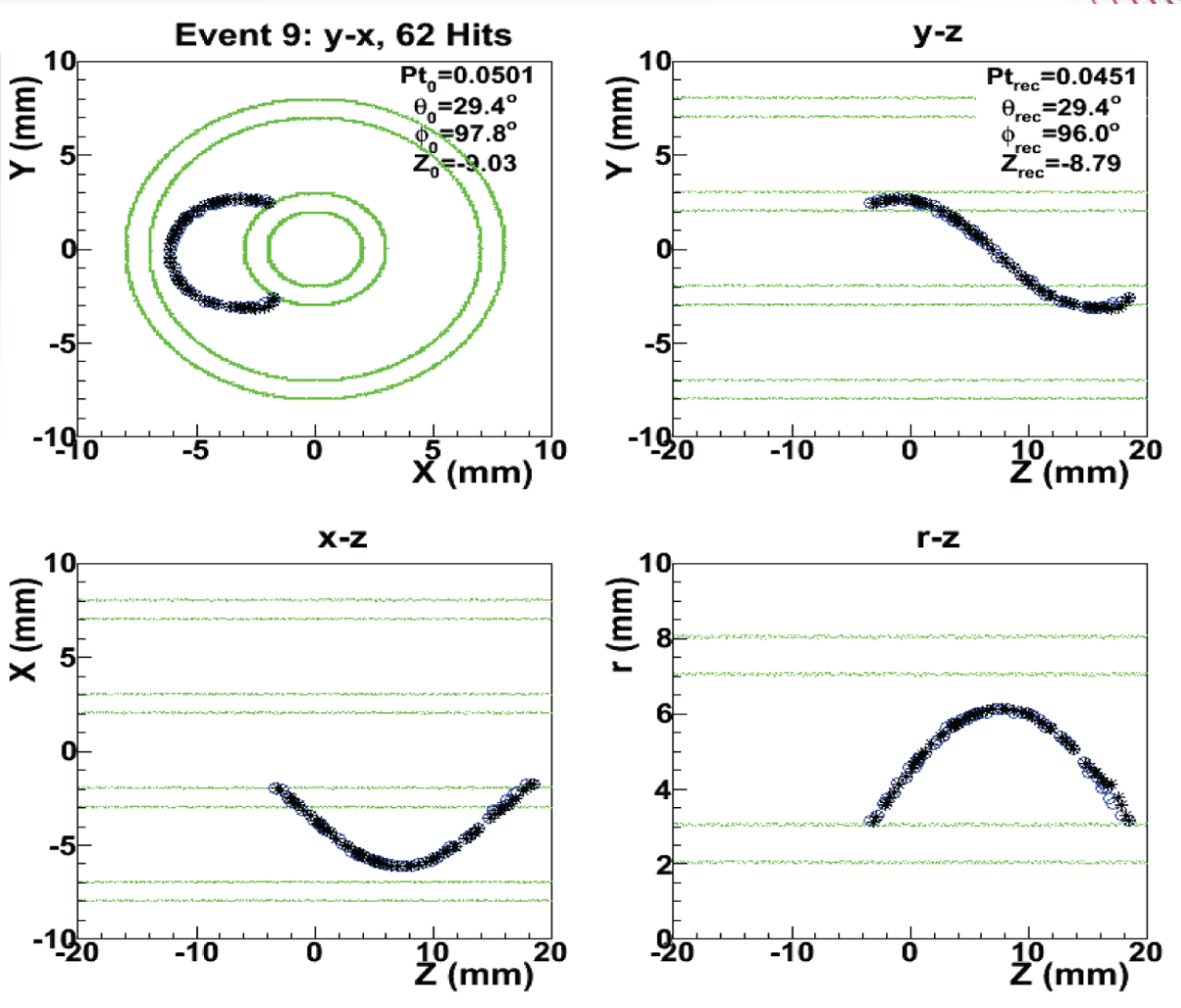
- Last January: MRI consortium formed
  - S. Bueltmann (PI), G.E. Dodge (Co-PI), S.E. Kuhn (Co-PI)
    Old Dominion University, Norfolk, VA
  - K. Griffioen (PI)
    The College of William and Mary, Williamsburg, VA
  - E. Christy (PI)
    Hampton University, Hampton, VA
  - I. Niculescu (PI), G. Niculescu (Co-PI)
    James Madison University, Harrisonburg, VA
- > 400k$ requested for development and construction of a new RTPC
- NSF approval pending…

Simulation

- Simulation and Analysis group:
  G. Dodge, S. Kuhn, N. Dzbenski, D. Payette, J. Zhang, K. Park;

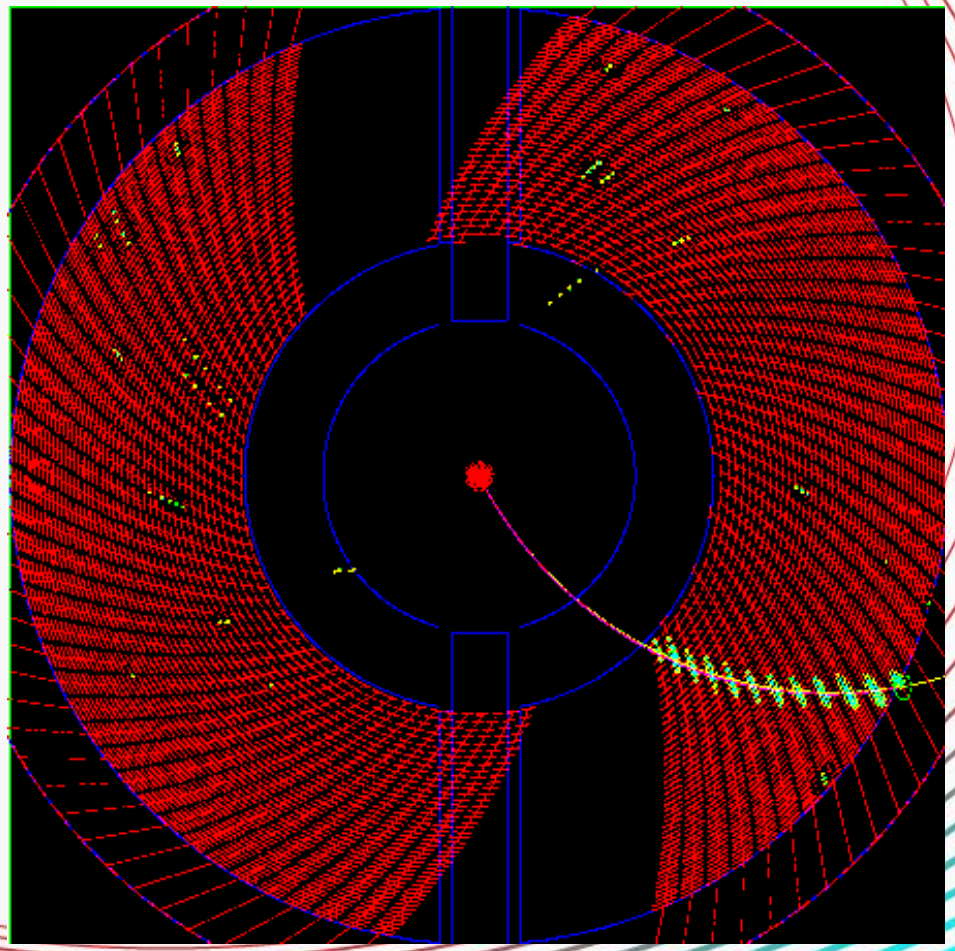
meetings Wednesdays at 3:00.





Drift Path of an Ionized Electron

- Simulation of E and B fields with MAGBOLTZ in a gas mixture.
- Determination of drift path and drift velocity of the electrons.
- Red lines->Drift path from each ionization electron to a given channel.
- Green-> spatial reconstruction of ionization place.
- Steps to reconstruction
  - Identify chains (candidate tracks)
  - Fit the candidate track through Kalman Filter.



Tracking

- Tracking Group: L. El Fassi, K. Adhikari, C. Ayerbe, K. Park, **J. Zhang**. **Meetings on Fridays at 1:00 p.m**

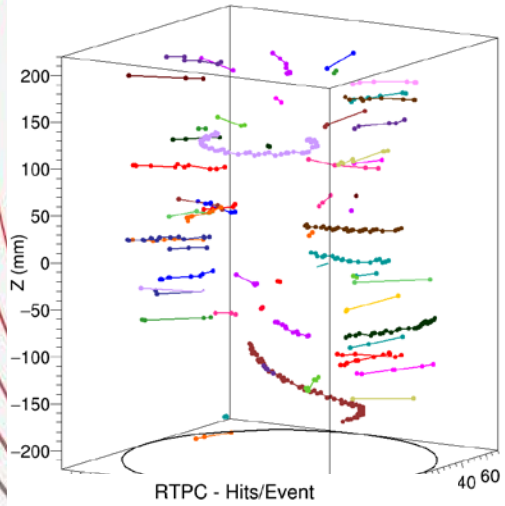
- Two issues to solve:
  - Track finder
  - Fitting tracks
- Tracks to test code from Geant4 simulation.

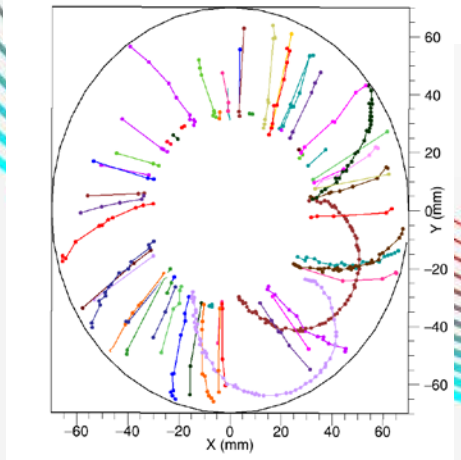
Track Finder I

- Naïve Track Following method, based on H. Fenker code for BONuS6. Works well but:
  - Can’t resolve crossing tracks.
  - Can’t resolve tracks split between two time windows
- BONuS 12:
  - Higher luminosity increases the probability of crossing tracks and more tracks split.
  - More events cause false ID of tracks.
  - An angular constrain is used in the search code to improve the search (IN TESTS)

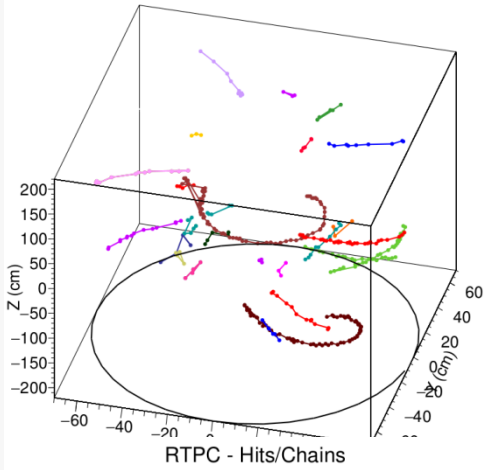
Track Finder II

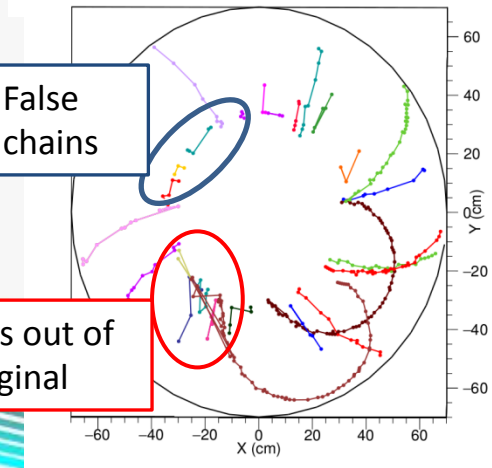
Simulated events (QE and ELA)





Found Events (simple space inspection)

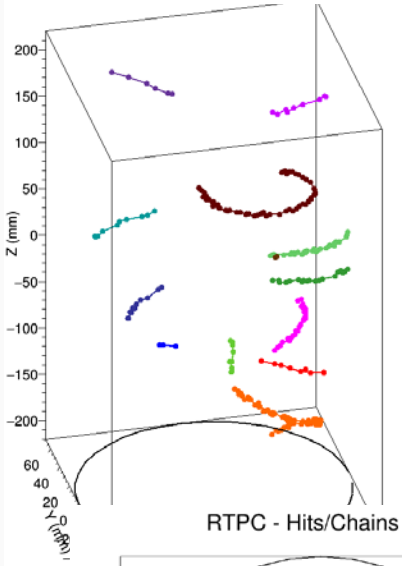


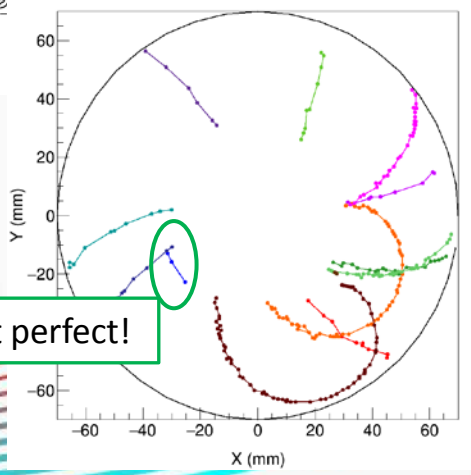


False chains

Hits out of original

Found Events (ang- spa inspection)

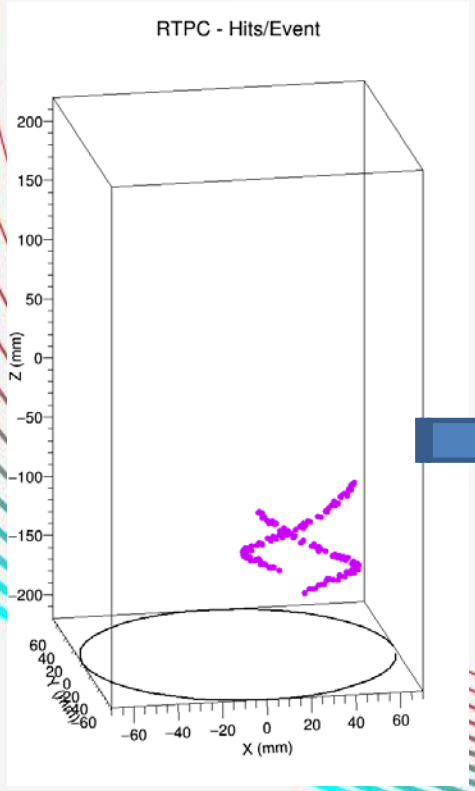




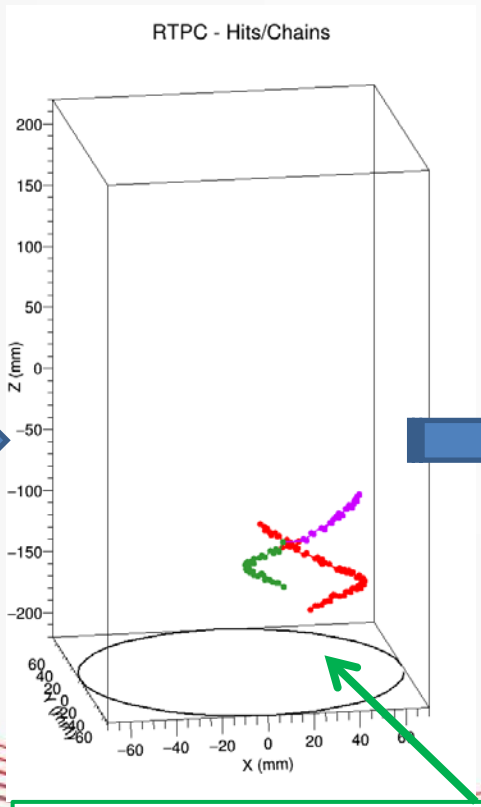
Not perfect!

Track Finder III

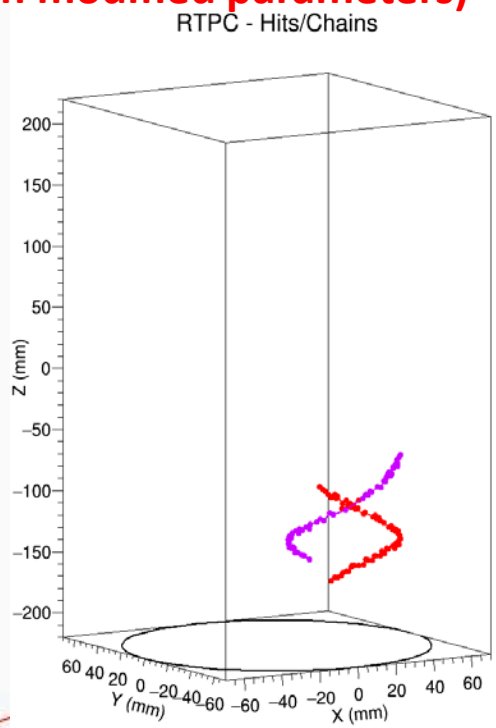
Crossing chains



Found chains (enhanced code)



Found chains (2nd pass of the code with modified parameters)

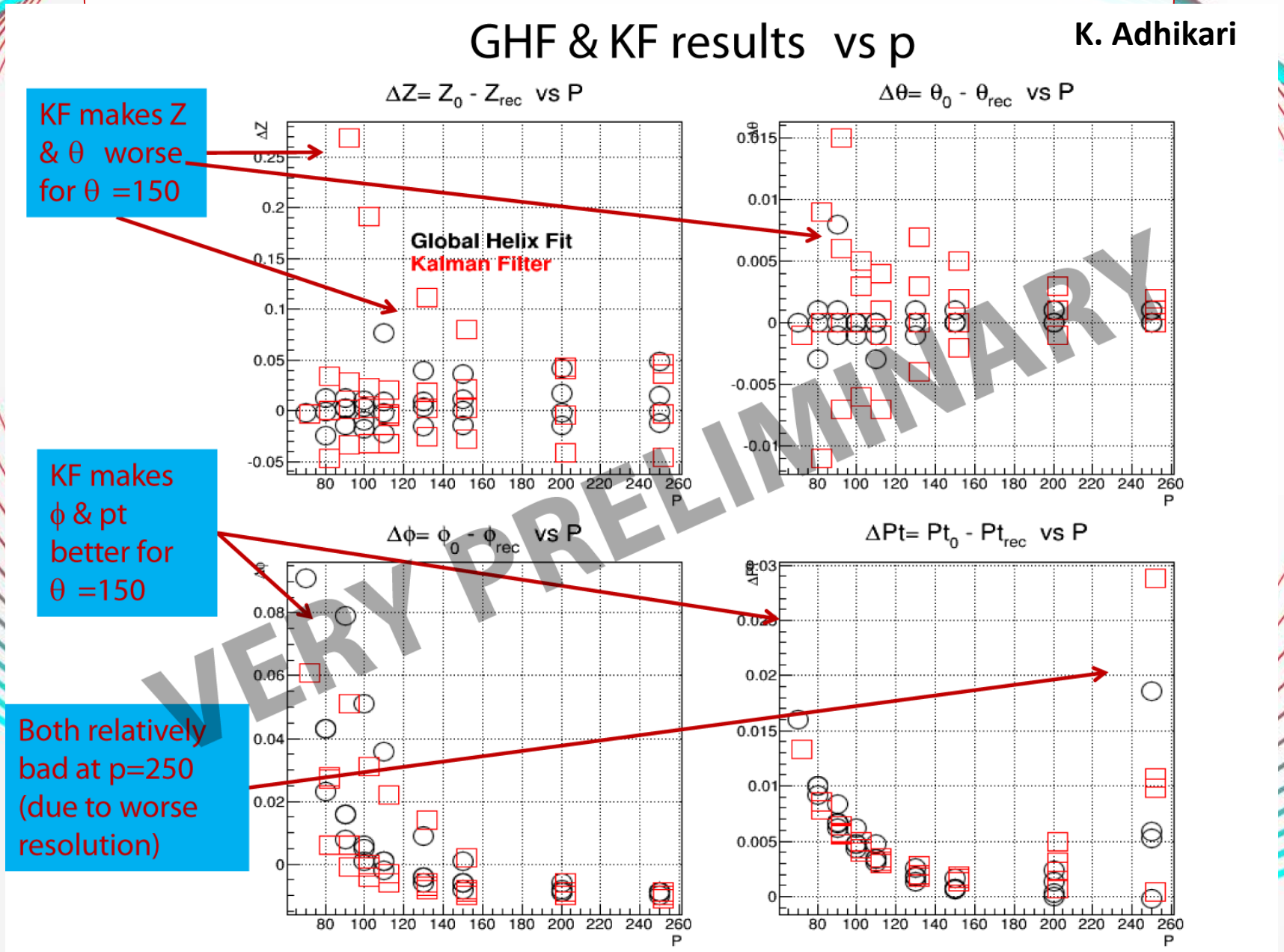


Now, we have 3 consecutive events

Kalman Filter I

- Candidate tracks->Fit with Kalman Filter-> p_t, θ, ϕ and z.
- Results are compared with parameters extracted using global helix fitter from BONuS6.

Kalman Filter II



Summary and Outlook

- ✓ BONuS@CLAS will measure the neutron structure function at large x_B through the spectator tagging technique.
- ✓ RTPC is the detector designed to make use of such technique.
  - ✓ Previous BONuS experiment have shown good agreement with other extraction techniques of F_{2n}
- ✓ An MRI for a new RTPC has been submitted.
- ✓ Analysis tools are in development:
  - ✓ Simulation
  - ✓ Track finder
  - ✓ Kalman Filter
- ✓ Many other physics topics could make advantage of BONuS with small modifications.

- ➢ Construction and tests of different sections of the new RTPC has just started.

BONuS collaboration has biweekly meetings on Thursdays at Jlab.

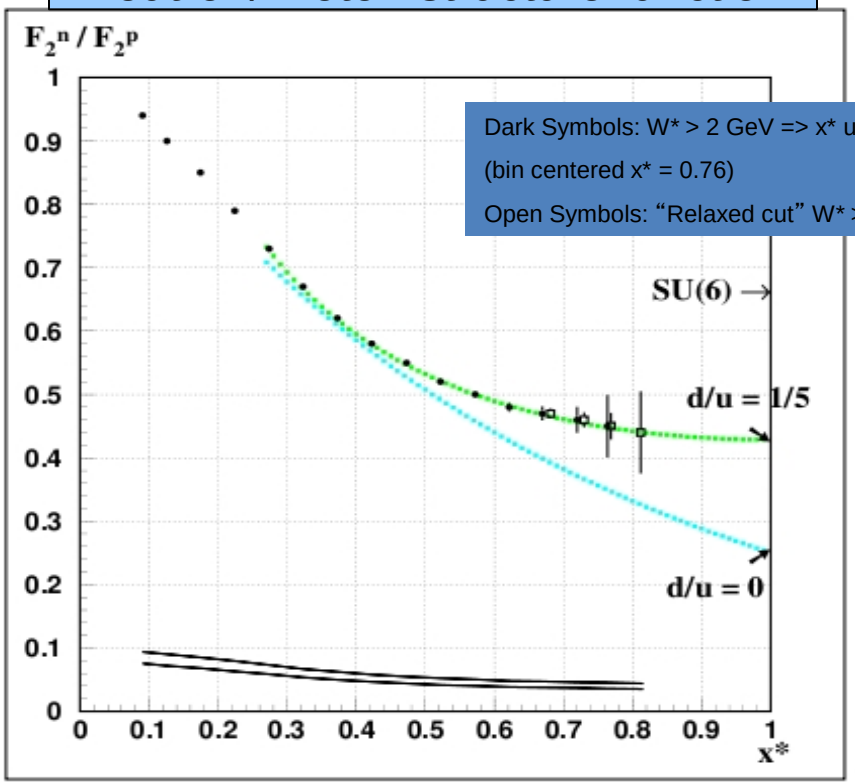
You are welcome to participate

THANK YOU FOR YOUR ATTENTION

BACKUP

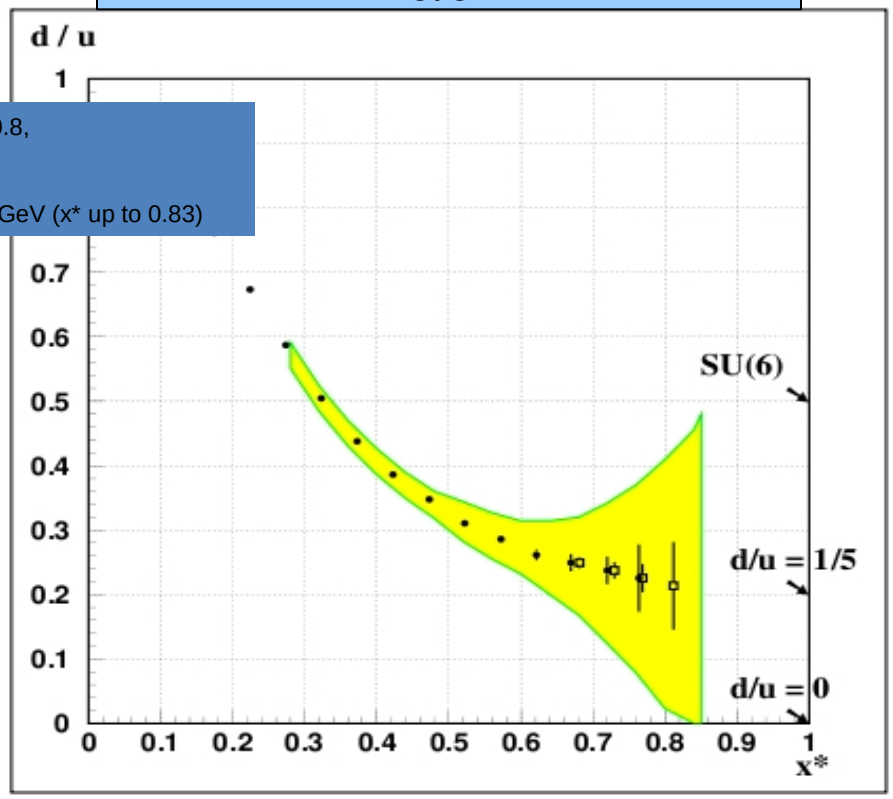
Expected Results

Neutron/Proton structure function



Dark Symbols: W* > 2 GeV => x* up to 0.8,
(bin centered x* = 0.76)
Open Symbols: "Relaxed cut" W* > 1.8 GeV (x* up to 0.83)

d/u



Data taking of 35 days on D_2 and 5 days on H_2 with $L = 2 \cdot 10^{34}$ cm^{-2} sec^{-1}

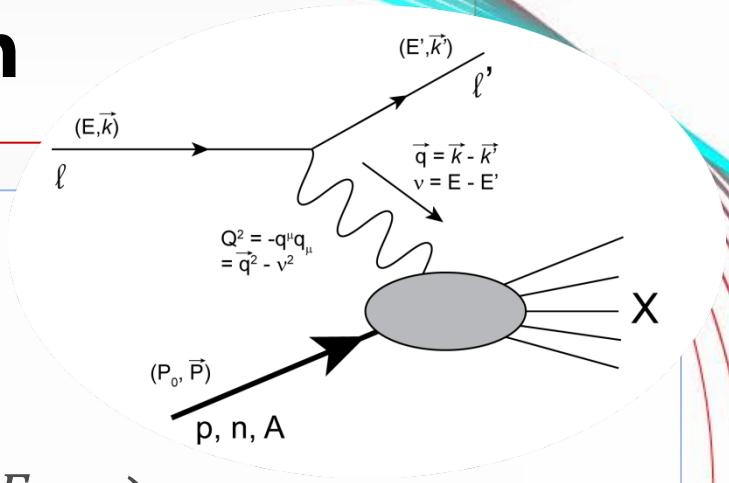
- DIS region with
  - $Q^2 > 1$ GeV$^2/c^2$
  - $W^* > 2$ GeV
  - $p_s > 70$ MeV/c
  - $-10° < \theta_{pq} < 170°$

More than F_{2n}

- With BONuS technology more research topics are available:
  - Semi-Inclusive Meson Production
  - Pion Cloud of the Nucleon
  - Semi-Inclusive DIS from A=3 Nuclei
  - Deeply-Virtual Compton Scattering
  - Exclusive and semi-inclusive physics of light nuclei
  - EMC effect in light nuclei

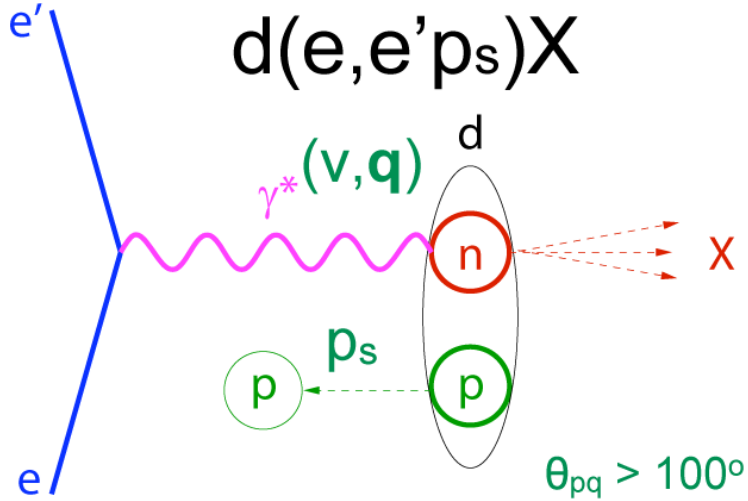
Just waiting for a proposal!!

DIS Formalism



- The DIS cross-section can be written as:
- $\frac{d\sigma}{d\Omega dE'} = \sigma_{Mott}\left(\frac{F_2(x)}{\nu} + 2\tan\frac{\theta_e}{2}\frac{F_{1(x)}}{M}\right)$
- $F_1(x) = \frac{1}{2}\sum_i {e_i}^2 f_i(x)$; $F_2(x) = xF_1(x)$ structure functions.
- $f_i(x)$ probability that a struck parton of kind i *and charge* e_i carries momentun fraction $x = \frac{Q^2}{2M\nu}$

Spectator Tagging Technique I



Keith Griffioen
DIS 2011

Detect the spectator proton from deuterium following *en* scattering. Make kinematic corrections using the spectator proton's energy E_s and momentum p_s.

$\theta_{pq} > 100^o$

$70 < p_s < 100$ MeV/c

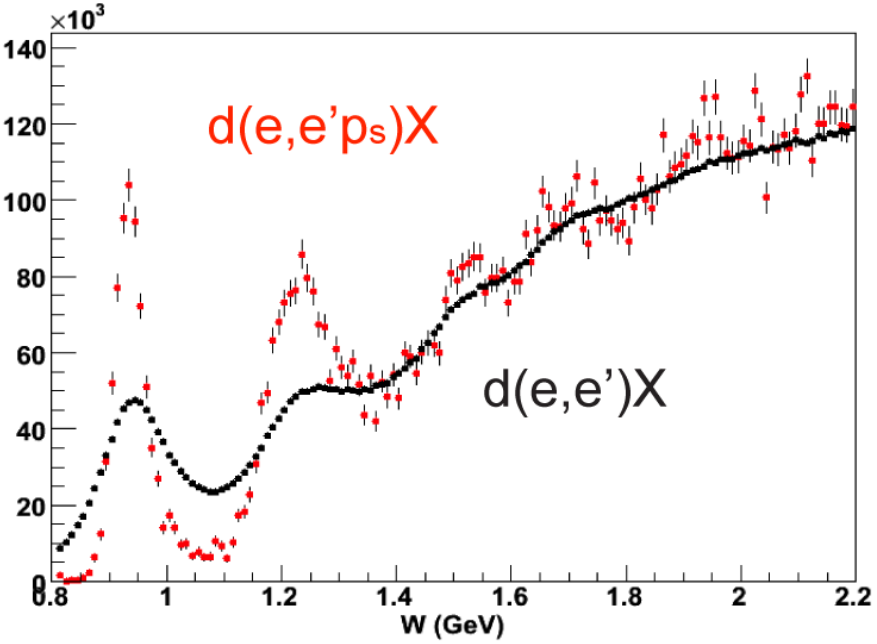
$E_{beam} = 4$ & 5 GeV

$$\alpha_s = \frac{E_s - p_{s_{||}}}{M_s}$$

$$M^{*2} = (M_d - E_s)^2 - \vec{p}_s^{\,2}$$

$$W^{*2} \approx M^{*2} - Q^2 + 2M\nu\,(2 - \alpha_s)$$

$$x^* = \frac{Q^2}{2p_N^\mu q^\mu} \approx \frac{Q^2}{2M\nu(2-\alpha_s)} = \frac{x}{2-\alpha_s}$$



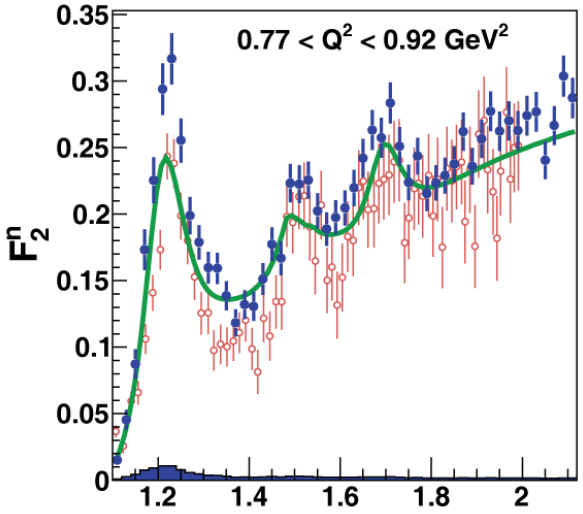
Results from BONuS6

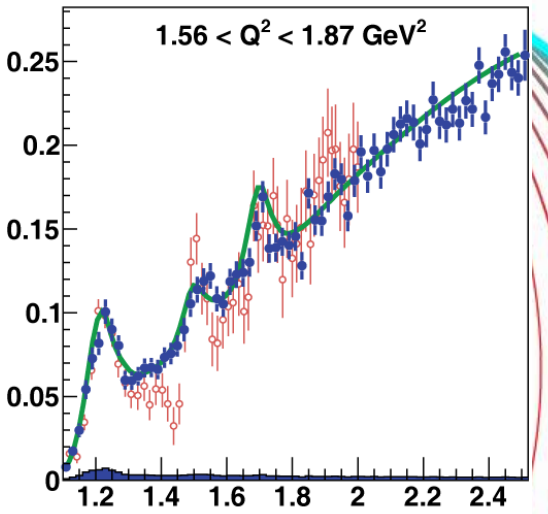
Some data results compared to a state of the art nuclear physics extraction of F_{2n} from Deuterium and a phenomenological parametrization

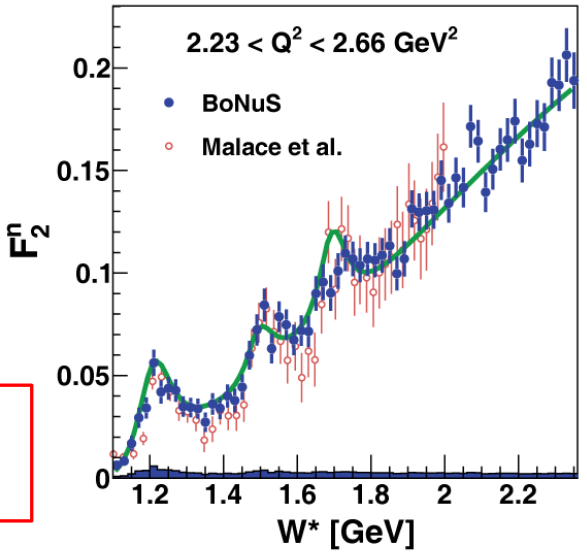
(S.P. Malace et. al.
Phys Rev Lett. 104, 102001 (2010)

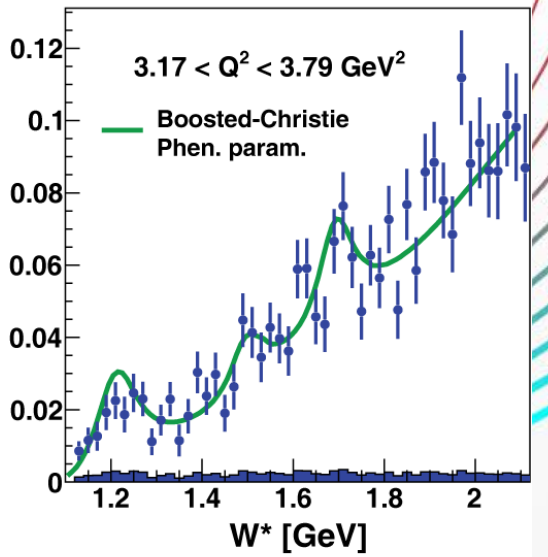
(P.E. Boosted and M.E. Christie,
Phys Rev. C 77, 065206 (2008).

N. Baillie et. al. Phys Rev Lett. 108, 104001 (2014)





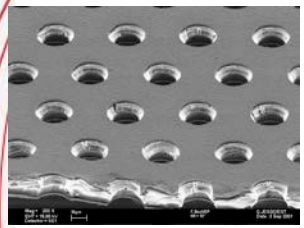




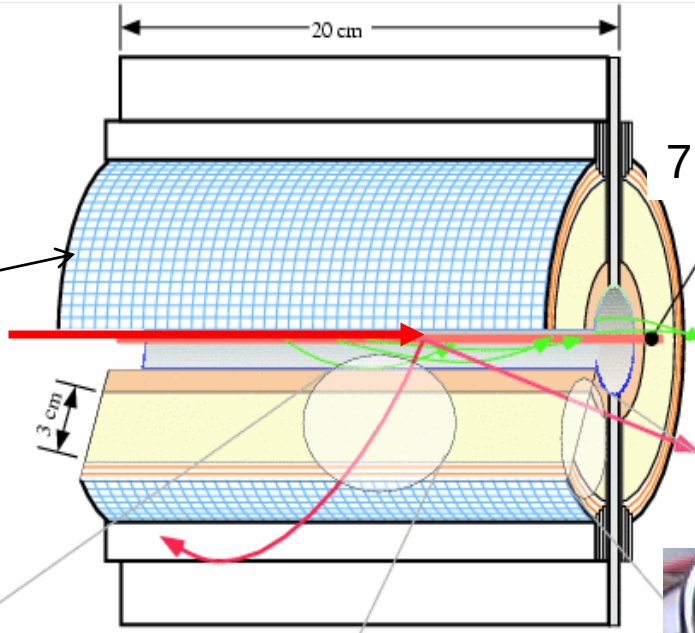
Motivation I

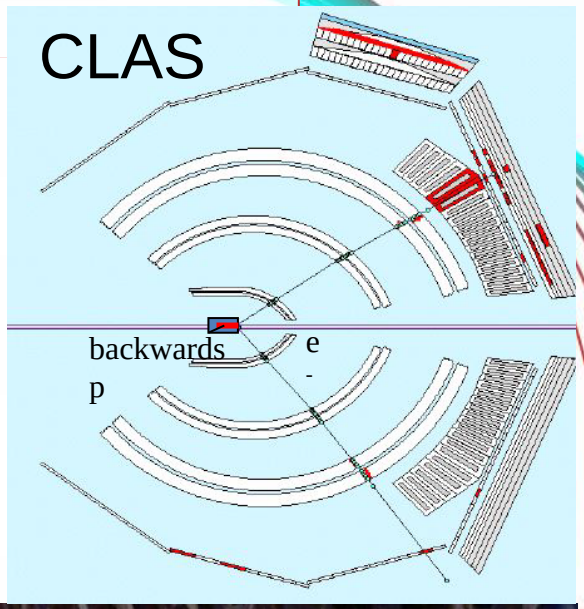
- With the use of inelastic lepton scattering:
  - Proton structure well studied for several decades.
  - Neutron structure less known.
- No free neutron target
  - Decay in 15 min -> radioactivity
  - Zero charge makes difficult create a dense target
  - Alternatives: **Deuterium**, ^{3}He
- Neutron function structure extracted indirectly -> many uncertainties to consider to correct.

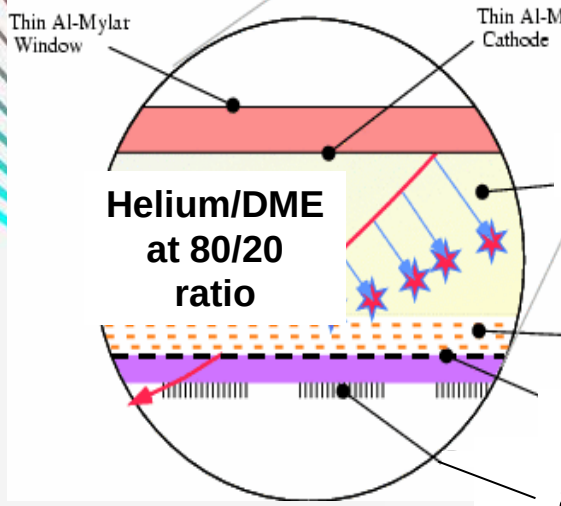
BONuS 6 RTPC



Gas
Electron
Multiplier



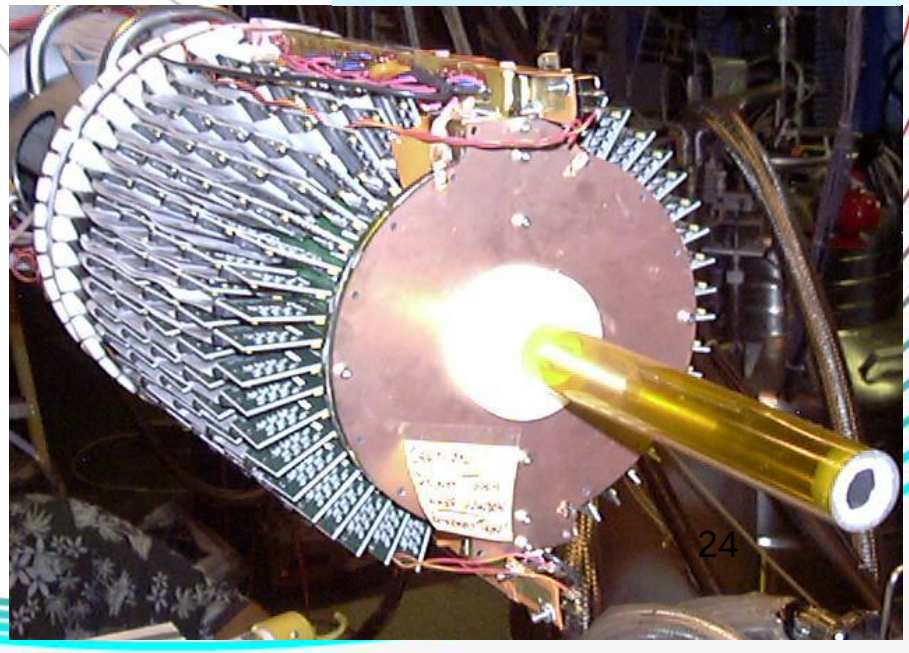




Drift Region

3 GEMs

Readout pads and electronics



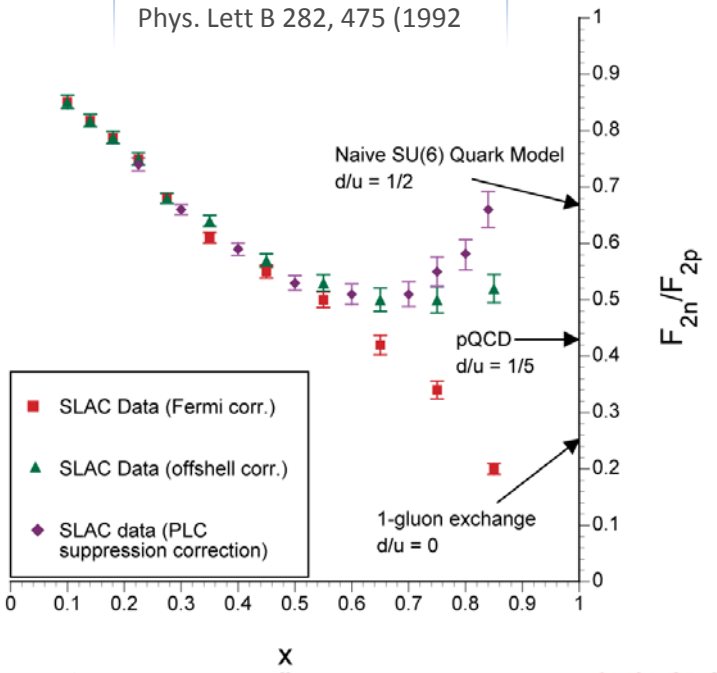
Motivation II

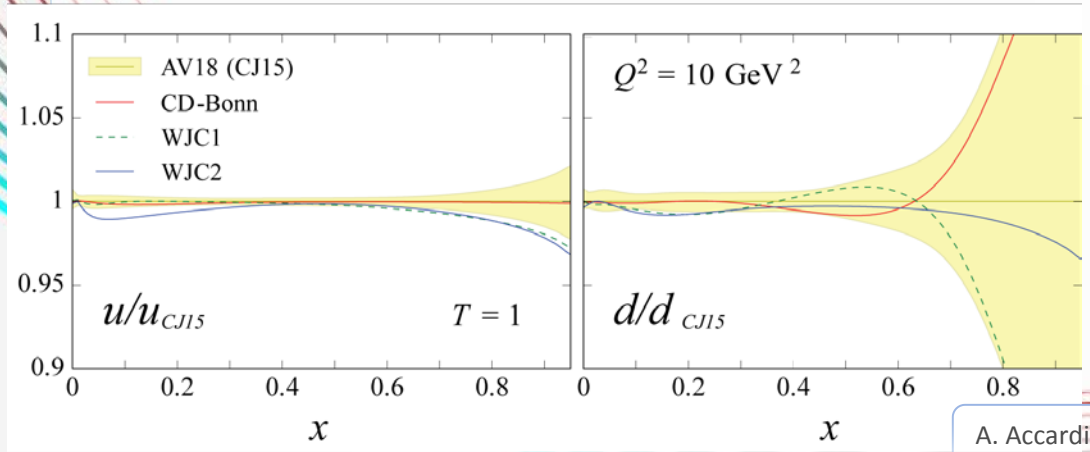
- Neutron structure function extracted from Deuteron structure function -> model dependent
- The structure functions give access to PDFs

$$\frac{F_2^n}{F_2^p} \approx \frac{1+4\,d/u}{4+d/u} \Rightarrow \frac{d}{u} \approx \frac{4\,F_2^n/F_2^p - 1}{4 - F_2^n/F_2^p}$$

- PDFs behavior unknown for x->1

L.W. Whitlow *et.al*
Phys. Lett B 282, 475 (1992





A. Accardi
arXiv:1602.03154

More detail N. Kalantarians, Users Group Meeting Monday June 20th 3:05pm